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# Effects of Certain Soil Conditions and Treatments Upon Potato Yields and the Development and Control of Potato Scab

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Lack of lime is a frequent cause of clover failures on Maine potato soils. With judicious use of lime satisfactory clover stands can usually be obtained on most soils without potato scab becoming a problem.

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## SUMMARY

This bulletin summarizes data from two potato scab and liming experiments conducted at Presque Isle, Maine, over the period of 1935 to 1947. The results of most interest are as follows:

1. Development of potato scab was closely related to the amount of ground limestone applied and the resulting pH and calcium content of the soil.
2. Scab increased more rapidly and became more severe on the less acid, darker and poorly drained Washburn loam than it did on the more acid, lighter colored and well-drained Caribou loam soil.
3. Severe infections of scab can be markedly reduced and sometimes eliminated by one or two applications of sulfur or ammonium sulfate.
4. The amount of scab reduction resulting from application of these soil-acidifying materials is closely related to the amount of scab prevailing and to the pH and other soil characteristics.
5. Potato yields were significantly greater in the pH range of 4.55 to 6.00 than at very higher or much lower soil pH levels.
6. Finely ground sulfur applied at the rate of one ton per acre in 1935 was very toxic to potatoes and other crops for one to three years. Applications of 300, 600, and 900 pounds of sulfur in 1946 were not toxic and had little effect on potato yields.
7. The extra nitrogen applied in the ammonium sulfate treatments increased yields of Green Mountain potatoes in the relatively late growing season of 1946, but caused decreased yields in the 1947 season, cut short by early frost.
8. There was little difference in the effect of various green manure crops and of organic treatments with stable manure, straw, or peat on either potato yields or development of potato scab.
9. A ton of ground limestone applied on an acid Caribou loam resulted in a good stand of mammoth clover, while with 500 and 1000 pound applications, the stand was absent to poor.

See pages 28-31 for Recommendations.

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BULLETIN 463

# EFFECTS OF CERTAIN SOIL CONDITIONS AND TREATMENTS UPON POTATO YIELDS AND THE DEVELOPMENT AND CONTROL OF POTATO SCAB[1]

G. L. Terman, F. H. Steinmetz, and Arthur Hawkins[2]

## INTRODUCTION

Potato scab[3] continues to be a problem in commercial potato production. In 1941, it was estimated that nearly 5 per cent of the Maine potato crop was affectd by scab. In 1948, although no survey was made, many producers reported that their scab problem was becoming more serious. Whether the reported increase in scab is the result of increased use of lime on potato soils, depletion of organic matter by erosion and too frequent cropping to potatoes, frequent cropping to potatoes in itself, or other factors is not known. The limited control of potato scab which has been accomplished on potato soils of Maine has been largely the result of applying little or no lime to these soils. Maintenance of adequate lime and pH levels in the soil, however, is desirable for satisfactory yields of potatoes and rotation crops, especially legumes. Control of potato scab at pH levels which are favorable for desirable rotation crops thus continues to be an important economic problem.

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[1] This investigation was a cooperative project between the Maine Agricultural Experiment Station and the Bureau of Plant Industry, Soils and Agricultural Engineering, U. S. Department of Agriculture, Beltsville, Maryland.

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The authors wish to acknowledge the part several others had in the study. Dr. J. A. Chucka and D. B. Lovejoy, formerly of the Maine Station, started the plot work. Michael Goven, Paul Johnson, S. C. Junkins and others also aided in the plot work. Mildred R. Covell made statistical analyses of the data. Paul Carpenter and others made the chemical determinations. Stephen Northsen took the photographs of potato tubers.

[3] Common potato scab, *Actinomyces scabies* (Thax.) Güss.

## DESCRIPTION OF THE POTATO SCAB EXPERIMENT AT AROOSTOOK FARM

In 1935, a small field at Aroostook Farm, Presque Isle, Maine, was divided into two sections (Sections I and II), each consisting of 100 plots 1/80 acre in size to study potato scab. The plots were 16½ by 33 feet, separated by a 3-foot border in which an unfertilized row of potatoes was planted. Each plot was planted to 6 rows of potatoes running lengthwise.

The soil on which the plots were located varied from a fairly well-drained Caribou gravelly loam to a rather poorly drained Washburn gravelly loam. Areas with intermediate drainage are classified as Easton gravelly loam. The nature of the drainage is indicated by the gradation from the brown, well-drained surface soil of the Caribou series to the grayish to dark, poorly-drained surface soil of the Washburn series. A drainage-way running somewhat diagonally through a portion of Section I caused great variability of the soil in this section. Since neither the yield of potatoes nor scab development on a large part of this section was similar to the rest of the experimental area, data from only 30 plots of Section I were summarized. Data from 80 plots on Section II were summarized.

Inorganic soil amendments to adjust the soil to different acidity, or pH levels, were applied in the fall of 1935. It was planned that pH levels of 4.5, 5.0, 5.5, 6.0, and 6.5 be established. The following soil amendments were applied across series of plots of each section in an east-west direction, respectively: 2000 pounds finely ground sulfur, nothing, and 2000, 4000, and 6000 pounds of finely ground limestone per acre. These soil amendments were replicated on each section, resulting in a duplicate set of plots planted to potatoes each year.

In 1936 a 2-year rotation of potatoes and green manure crops or oats with additional organic soil treatments was began. These crops were planted and the organic treatments were applied on strips of plots in a north-south direction across the replications of the inorganic soil amendment strips. Grain and straw were removed from the plots on which oats were planted. In the fall the organic soil treatments (manure, straw, and peat), were applied and the entire section plowed in preparation for potatoes the following spring. The field plan for Section II is shown in Figure 1.

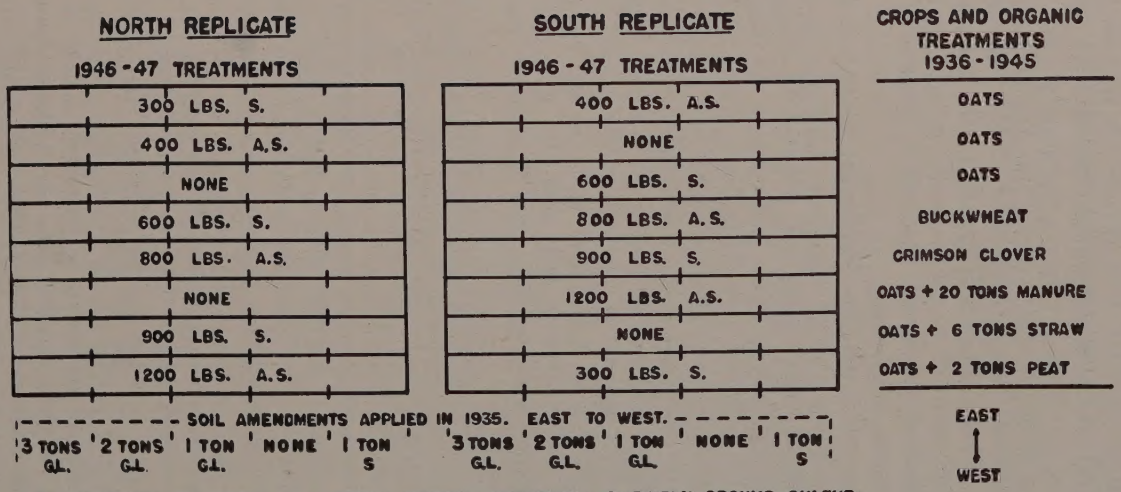


FIGURE 1. Potato scab experiment at Aroostook Farm, Presque Isle, Maine—Arrangement and treatment of plots of Section II.

The inorganic soil amendments and potato yields are given in Table 1, while the green manure crops and other organic treatments with potato yields are given in Table 8.

Two additional strips of plots were reserved for a study of chemicals applied in the fertilizer for control of scab. These chemicals were applied, however, only in 1936, when little scab developed. Thus no data of value on this phase of scab control were obtained.

Except for 1936 and 1937, when the Irish Cobbler variety was planted, the Green Mountain variety of potatoes was grown. Both varieties are highly susceptible to scab.

A uniform rate of fertilizer was applied to all plots planted to potatoes. No fertilizer was applied in the alternate year. From 1936 to 1942 the potato fertilizer consisted of 1000 pounds of 8-16-16 or 8-16-20 per acre. For the 1943 and 1944 potato crops, fertilizer was applied at the rate of 1600 pounds of 6-9-15 per acre. In 1946 a ton of 5-7-10 and in 1947 a ton of 5-9-9 was applied for potatoes.

In 1946, treatments with ammonium sulfate and sulfur were superimposed upon Section II of the experimental area, used up to this time to study scab development. The plots of Section I were discontinued. Each treatment (see Figure 1) was replicated on strips of plots in a north-south direction across the inorganic amendments applied in 1935. In 1947 Section II was again planted to potatoes. Ammonium sulfate was applied to the same strips and at the same rates as in 1946, but the sulfur treatments were not repeated.

## EFFECT OF INORGANIC SOIL AMENDMENTS AND SOIL pH ON YIELD OF POTATOES

*Ground Limestone and Sulfur Applied in* 1935. A comparison of potato yields on unlimed plots, as compared to plots on which 1, 2, or 3 tons of ground limestone was applied per acre, indicates in general that liming was not beneficial on this particular soil area. Neither the pH nor calcium content of the soil was sufficiently low at the start of the experiment for lime to result in higher yields, as often results on more acid soils. Only in 1940 did any rate of liming significantly increase yield, as indicated in Table 1. In most

TABLE 1

*Effect of Ground Limestone and Sulfur on Yield of Potatoes from 1936 to 1945*

| Amendments[1] applied in fall of 1935— Acre rate | Intended soil pH | Yield—Bushels per acre[2] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1936[3] | 1937 | 1938 | 1939 | 1940 | 1941 | 1942 | 1943 | 1944 | 1945 | Av. for Sec. I (odd years) | Av. for Sec. II (even years) |
| 6000 lbs. ground limestone | 6.5 | 511 | 342 | 341 | 377 | 380 | 467 | 404 | 500 | 412 | 363 | 410 | 384 |
| 4000 lbs. ground limestone | 6.0 | 536 | 356 | 356 | 384 | 402 | 447 | 416 | 489 | 426 | 370 | 409 | 400 |
| 2000 lbs. ground limestone | 5.5 | 548 | 367 | 347 | 371 | 375 | 468 | 413 | 507 | 424 | 382 | 419 | 391 |
| Nothing | 5.0 | 549 | 367 | 356 | 391 | 369 | 495 | 435 | 497 | 418 | 391 | 428 | 395 |
| 2000 lbs. sulfur | 4.5 | 136 | 269 | 332 | 299 | 338 | 467 | 419 | 485 | 393 | 372 | 378 | 371 |
| Significant difference:[4] | | | | | | | | | | | | | |
| 5% level | — | 25 | 28 | N.S. | 28 | 27 | 28 | N.S. | N.S. | 19 | 28 | 13 | 11 |
| 1% level | — | N.S. | 37 | N.S. | 37 | 37 | 37 | N.S. | N.S. | 25 | N.S. | 17 | 15 |

[1] Amendments applied in an attempt to adjust soil to the pH values listed. See Table 4 for actual mean pH values.

[2] Potatoes were grown on Section I in odd years and on Section II in even years. Green manure crops were grown in alternate years on each section.

[3] Because of marked reduction in yield from the sulfur treatment, 1936 yield data were not included in the combined statistical analysis for the 5 crops on Section II.

[4] Because of lack of replication in odd years, the significant difference for these years was calculated from the combined data, using years as replications. Significant differences for each even year were calculated from each year's data. N.S.—Differences not statistically significant.

years all rates of liming resulted in slight to significant decreases in yield.

The application of a ton of sulfur per acre in 1935 to produce a low soil pH was very toxic to the first crop of potatoes grown on Section II in 1936. On some plots injury to the young plants was so great that practically no stand of potatoes survived. The tubers produced also showed injury. As indicated in Table 1, the yield of potatoes was reduced more than 400 bushels per acre by the sulfur application. Its marked toxic effect, however, largely disappeared by the time the next crop of potatoes was grown on this section in 1938. On Section I the sulfur caused a reduction in yield of about 90 bushels per acre in 1937 and 80 bushels in 1939. By 1941, when the third crop of potatoes was grown on these plots, the sulfur was no longer very injurious. Somewhat lower yields on the sulfur-treated plots, however, persisted throughout the duration of the experiment. The lower yields on these plots during the latter years probably resulted from the low soil pH on these plots caused by the sulfur application.

*Sulfur and Ammonium Sulfate*[4] *Applied at Different Rates in 1946 and 1947.* Sulfur was applied in 1946 at rates of 300, 600 and 900 pounds per acre to study its effect in reducing potato scab. These sulfur treatments were not repeated in 1947 because of the possible toxic effect of the higher rates, as resulted from the 2000 pound application in 1935. None of the rates of sulfur applied in 1946 had a significant effect on yield in either 1946 or 1947.

Ammonium sulfate, applied at different rates in both 1946 and 1947, did have significant effects on potato yields, as indicated in Table 2. In both years each application produced a luxuriant vine growth with dark green foliage, which remained green until killed by frost. In 1946 the tops were not killed until October 7. As a result, the additional nitrogen applied caused some increase in yield for the 400 pound per acre rate of ammonium sulfate and significant increases for the 800 and 1200 pound rates over plots receiving only the regular row fertilizer, which served as the check treatment. In 1947 the 1200 pound rate of ammonium sulfate resulted in a significant decrease in yield of potatoes and the lower rates reduced the yield appreciably, as compared to the check

[4] Ammonium sulfate for these experiments was contributed by the Coke Oven Ammonia Research Bureau, Columbus, Ohio.

TABLE 2

*Effect of Acidifying Treatments Applied in 1946 and 1947 on Yield of Potatoes on Section II*

| Treatment applied Acre rate | Yield for 1935 amendments—Bushels per acre | | | | | |
|---|---|---|---|---|---|---|
| | 6000 lbs. gr. limestone | 4000 lbs. gr. limestone | 2000 lbs. gr. limestone | Nothing | 2000 lbs. sulfur | Average [1] |
| 1946 | | | | | | |
| Nothing | 467 | 476 | 520 | 513 | 488 | 493 |
| 300 lbs. sulfur | 494 | 493 | 494 | 492 | 455 | 486 |
| 600 lbs. sulfur | 494 | 495 | 499 | 512 | 426 | 485 |
| 900 lbs. sulfur | 521 | 538 | 560 | 526 | 465 | 522 |
| 400 lbs. ammon. sulfate | 506 | 519 | 542 | 515 | 552 | 527 |
| 800 lbs. ammon. sulfate | 555 | 588 | 575 | 566 | 495 | 556 |
| 1200 lbs. ammon. sulfate | 539 | 567 | 627 | 587 | 529 | 570 |
| Average, 1946[2] | 511 | 525 | 545 | 530 | 487 | |
| 1947 | | | | | | |
| Nothing | 505 | 509 | 530 | 534 | 489 | 513 |
| No additional sulfur | 504 | 518 | 511 | 503 | 497 | 507 |
| No additional sulfur | 490 | 529 | 541 | 540 | 472 | 514 |
| No additional sulfur | 513 | 538 | 522 | 542 | 468 | 517 |
| 400 lbs. ammon. sulfate | 494 | 511 | 511 | 513 | 510 | 508 |
| 800 lbs. ammon. sulfate | 511 | 520 | 505 | 510 | 450 | 499 |
| 1200 lbs. ammon. sulfate | 488 | 496 | 479 | 456 | 438 | 471 |
| Average, 1947[2] | 501 | 517 | 514 | 514 | 475 | |

[1] Significant differences for these averages are as follows:
1946—5% level, 44 bu. and 1% level, 59 bu.
1947—5% level, 26 bu. and 1% level, 35 bu.

[2] Significant differences for these averages for 1935 treatments are as follows:
1946—5% level, 35 bu. and 1% level, N.S.
1947—5% level, 21 bu. and 1% level, 28 bu.

treatment. In this crop year the vines were killed by frost on September 19. The shorter growing season, together with the effect of the excess nitrogen in delaying maturity, apparently caused the yield reduction, especially on the plots receiving the 1200 pound rate of ammonium sulphate.

*Effect of Soil pH on Yields.* Largely because of previous soil variability, the pH of the soil on different plots receiving a given inorganic soil amendment in 1935 varied considerably throughout the duration of the experiment. The extent of this variation in pH at different sampling dates is shown in Table 4. The data in Table 3 show the relation between potato yields and ranges of soil pH values, disregarding certain nutritional effects of the various treatments on yield. Highly significant differences between yields for the different pH ranges were found in five out of seven years in which potatoes were grown on Section II. Because of insufficient numbers of plots on the portion of Section I summarized, these

data are not given. In general, highest yields were obtained on plots having pH values between 4.55 and 6.00. Yields were somewhat lower either below or above this pH range. Similar effects of soil pH or fertility conditions associated with different pH levels on potato yields in New York have been noted by other investigators (5, 7).[5]

TABLE 3

*Relation of Actual Soil pH Values by Ranges to Yield of Potatoes on Section II*

| Soil pH range[1] | Yield—Bushels per acre | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1936 | 1938 | 1940 | 1942 | 1944 | 1946 | 1947 |
| 6.55–7.50 | 520 | 345 | 364 | — | — | — | — |
| 6.05–6.50 | 523 | 349 | 390 | 369 | 375 | — | 511 |
| 5.55–6.00 | 532 | 349 | 384 | 438 | 424 | 503 | 511 |
| 5.05–5.50 | 549 | 362 | 371 | 448 | 425 | 538 | 522 |
| 4.55–5.00 | — | — | 338 | 428 | 421 | 539 | 509 |
| 4.05–4.50 | — | — | | 418 | 385 | 479 | 457 |
| 3.55–4.00[2] | 136 | 332 | — | — | — | — | — |
| Significant difference: | | | | | | | |
| 5% level— | N.S. | N.S. | 31 | 25 | 18 | 34 | 19 |
| 1% level— | N.S. | N.S. | 41 | 33 | 24 | 45 | 25 |

[1] Different levels of soil pH were produced over the period of 1936 to 1945 by additions of ground limestone and sulfur, as indicated in Table 4. Further changes were caused by additions of ammonium sulfate and sulfur in 1946 and ammonium sulfate alone in 1947.

The pH values of samples taken in 1937 were used for 1936 and 1938. Values used for 1942 were averages of pH values of samples taken in 1940 and 1944. Values for remaining years are for samples taken in each of those years.

[2] Data from plots having pH values of 3.55–4.00 were not included in the analysis, because of marked yield reduction from sulfur on these plots. N.S.—Differences not statistically significant.

## EFFECT OF INORGANIC SOIL AMENDMENTS ON POTATO SCAB AND SOIL pH

*Development of Scab and Method of Estimation.* After the applications of ground limestone and sulfur as soil amendments in 1935, only minor amounts of potato scab developed on most plots. An exception was on certain plots along one edge of Section II which were limed at the rate of 3 tons per acre. In this case the early development of scab apparently resulted from the residual effect of stable manure having been piled on this place at times prior to 1935. Four plots at this location had considerable tuber

[5] Figures in parenthesis refer to "Literature Cited," page 31.

scab in 1936 and it became severe in 1938. Other plots of Section II had insufficient scab in the years 1936-38 for comparisons between treatments. In order to insure uniform distribution of the scab organisms, scabby seed potatoes were planted the first and second crop year. By 1939, practically all plots limed at the three-ton rate produced tubers badly infected with scab, while tubers from plots limed at the one and two-ton rates varied from clean to slightly scabby.

In the years 1939-42 an estimate was made of the percentage of tubers from plots of the entire experiment which had noticeable scab lesions. This method gave somewhat questionable values, since it was influenced considerably by personal judgment and did not differentiate between slightly and severely scabbed potatoes.

Starting with the 1943 crop a value termed the scab index was calculated for each plot. The procedure was as follows: Four to six-bushel samples, one bushel of field-run tubers from each row, were sorted into scab grades according to the estimated percentage of the tuber surface covered by scab lesions. The chart published by Clark *et al.* (1, page 881) was used as a reference in estimating the scab grades. The tubers were sorted into seven grades. These were clean (zero, no scab lesions), 1 per cent (usually one or two lesions), 10 per cent (arbitrarily used for range of 5 to 20), 30 per cent (21 to 40), 50 per cent (41 to 60), 70 per cent (61 to 80), and 90 per cent (81 to 100). See Figure 2 for the range in scabbiness of tubers.

After sorting into scab grades, the tubers in each grade were then weighed. For computation of the scab index, the weight in pounds of each grade was multiplied by the mid-point of its scab range, as given above. These products were then added and the sum divided by the total weight of tubers in all classes. The quotient, or scab index, is thus a weighted average of the percentage of the surface covered by scab lesions of tubers from a sample or plot. This value is believed to be a fairly accurate estimate of the percentage of the tuber surface covered with scab lesions.

Classification of the tubers into types of scab pustules as indicated by Stevenson *et al.* (6) was not done. While it is recognized that a certain type of russeting may be the result of the potato scab organism, no attempt was made to sort tubers on this basis. Such tubers were classed as clean, since Green Mountain tubers

FIGURE 2. Green Mountain tubers illustrating the tuber scab grades according to the percentage of the surface covered by scab lesions as follows:

Above—Clean, clean, 1 per cent, and 10 per cent.

Below—30 per cent, 50 per cent, 70 per cent, and 90 per cent.

Slight russeting, as shown on "clean" tubers, is considered normal for the Green Mountain variety grown in Aroostook County.

produced in Aroostook County in some years show partial to complete russeting when grown under practically any of the soil conditions prevailing. Schaal (4) considers russet type the form of scab lesion which occurs below pH 5.4. Lutman (2) considers that scab russeting is caused by *Actinomyces* hyphae in the intercellular spaces of epidermal cells of tubers but unrelated to deeper lenticel scab infections.

*Incidence of Potato Scab and Change in pH of Soil as Affected by Amendments Applied in 1935.* As shown in Table 4, the pH of the soil before application of amendments in 1935 varied considerably. This was due largely to the difference in soil type over the plot area. The rather poorly drained Washburn soil areas

TABLE 4

*Effect of Ground Limestone and Sulfur Applied in 1935 on pH of Soil at Different Sampling Dates*

| 1935 treatment and year of sampling on Section I[1] | pH of soil on Section I (part of north replicate) | | Year of sampling on Section II | pH of soil on Section II | | | |
|---|---|---|---|---|---|---|---|
| | | | | North replicate | | South replicate | |
| | Range | Average[2] | | Range | Average[2] | Range | Average[2] |
| 6000 lbs. ground limestone: | | | | | | | |
| 1935 | 5.20–5.60 | 5.30 | 1935 | 4.75–5.80 | 5.30 | 4.75–5.35 | 5.00 |
| 1937 | 5.80–6.10 | 6.00 | 1937 | 6.60–7.30 | 6.90 | 6.40–6.85 | 6.65 |
| 1939 | 6.20–6.75 | 6.40 | 1940 | 6.00–6.80 | 6.45 | 6.05–6.70 | 6.30 |
| 1945 | 5.90–6.15 | 6.05 | 1944 | 5.70–6.30 | 6.00 | 5.55–6.00 | 5.85 |
| 4000 lbs. ground limestone: | | | | | | | |
| 1935 | 5.10–5.35 | 5 20 | 1935 | 4.70–5.55 | 5.15 | 4.70–5.05 | 4.90 |
| 1937 | 5.55–5.95 | 5.75 | 1937 | 6.25–7.00 | 6.60 | 6.40–6.65 | 6.50 |
| 1939 | 6.10–6.35 | 6.20 | 1940 | 5.80–6.60 | 6.30 | 6.00–6.40 | 6.15 |
| 1945 | 5.60–6.00 | 5.85 | 1944 | 5.50–6.10 | 5.80 | 5.65–5.90 | 5.75 |
| 2000 lbs. ground limestone: | | | | | | | |
| 1935 | 5.20–5.30 | 5.25 | 1935 | 4.65–5.65 | 5.15 | 4.70–5.00 | 4.80 |
| 1937 | 5.40–5.65 | 5.50 | 1937 | 5.90–6.55 | 6.25 | 5.75–6.05 | 5.85 |
| 1939 | 5.45–5.80 | 5.60 | 1940 | 5.60–6.50 | 6.10 | 5.50–5.95 | 5.75 |
| 1945 | 5.30–5.80 | 5.60 | 1944 | 5.10–5.95 | 5.60 | 5.15–5.40 | 5.30 |
| No broadcast treatment: | | | | | | | |
| 1935 | 5.15–5.45 | 5.25 | 1935 | 4.80–5.60 | 5.15 | 4.70–4.80 | 4.75 |
| 1937 | 4.85–5.55 | 5 20 | 1937 | 5.20–6.00 | 5.50 | 5.10–5.55 | 5.30 |
| 1939 | 5.00–5.60 | 5.30 | 1940 | 5.15–6.00 | 5.55 | 5.20–5.35 | 5.25 |
| 1945 | 5.00–5.60 | 5.25 | 1944 | 4.80–5.55 | 5.10 | 4.70–4.95 | 4.85 |
| 2000 lbs. sulfur: | | | | | | | |
| 1935 | 5.10–5.45 | 5.30 | 1935 | 4.80–5.50 | 5.15 | 4.60–4.75 | 4.70 |
| 1937 | 3.90–4.65 | 4.25 | 1937 | 3.70–4.00 | 3.85 | 3.65–3.85 | 3.75 |
| 1939 | 3.75–4.50 | 4.30 | 1940 | 4.40–4.90 | 4.70 | 4.20–4.50 | 4.35 |
| 1945 | 4.40–4.75 | 4.60 | 1944 | 4.30–4.75 | 4.55 | 4.10–4.40 | 4.20 |

[1] The pH values for 1935 are of samples taken before amendments were applied.
[2] Average of 6 plots on Section I and of 8 plots on Section II. It is realized that averages of pH values give only approximations, but these were found to be very close to the true values, as found by converting each pH reading to hydrogen ion concentration, averaging and converting this value back to pH.

were somewhat higher in pH than the well-drained Caribou soil areas. The Washburn soil occupies a large portion of the north replicate of Section II, and as a result, the pH averages higher here than on the south replicate. The pH of the soil of the plots utilized on Section I varied in 1935 from 5.10 to 5.60, while on the north replicate of Section II the pH varied from 4.65 to 5.80, and the south replicate from 4.60 to 5.35. This original variability had considerable effect on the amount of scab which developed on different plots of a strip receiving a certain soil amendment.

As shown by the arithmetic means of the mean pH values (Table 4) for plots of the north and south replicates of Section II and of a part of the north replicate of Section I, application of ground limestone resulted in the following increases in pH in 1937 over the values for 1935: three tons, 1.30; two tons, 1.20; one ton, 0.80. During the following years the pH values on the limed

TABLE 5

*Effect of Inorganic Soil Amendments upon Scab Development in 1943-1945, as Indicated by Scab Index Values*

| 1935 treatment and year of harvest[1] | North replicate | | | South replicate | | |
|---|---|---|---|---|---|---|
| | Scab index values | | Average soil pH[2] | Scab index values | | Average soil pH[2] |
| | Range | Average | | Range | Average | |
| 6000 lbs. ground limestone: | | | | | | |
| 1943 | 31.0–61.0 | 47.4 | 6.20 | — | — | — |
| 1944 | 34.7–56.4 | 41.8 | 6.00 | 21.7–52.3 | 39.8 | 5.85 |
| 1945 | 24.3–56.5 | 43.6 | 6.05 | — | — | — |
| 4000 lbs. ground limestone: | | | | | | |
| 1943 | 9.7–41.2 | 22.6 | 6.00 | — | — | — |
| 1944 | 13.3–47.9 | 25.3 | 5.80 | 11.8–42.4 | 26.0 | 5.75 |
| 1945 | 9.4–27.2 | 19.1 | 5.85 | — | — | — |
| 2000 lbs. ground limestone: | | | | | | |
| 1943 | 0 –17.1 | 4.2 | 5.60 | — | — | — |
| 1944 | 0 –14.3 | 7.0 | 5.60 | 0 – 2.4 | 0.9 | 5.30 |
| 1945 | 3.8–11.7 | 6.7 | 5.60 | — | — | — |
| No broadcast treatment: | | | | | | |
| 1943 | 0 – 0.6 | 0.1 | 5.25 | — | — | — |
| 1944 | 0 – 3.1 | 1.0 | 5.10 | 0 | 0 | 4.85 |
| 1945 | 0.2– 3.2 | 1.3 | 5.25 | — | — | — |
| 2000 lbs. sulfur: | | | | | | |
| 1943 | 0 – 0.5 | 0.1 | 4.45 | — | — | — |
| 1944 | 0 – 0.3 | 0.1 | 4.55 | 0 | 0 | 4.20 |
| 1945 | 0 – 0.2 | 0.1 | 4.60 | — | — | — |

[1] Tubers harvested from Section I in 1943 and 1945 and from Section II in 1944.
[2] Average of 6 plots for 1943 and 1945 and of 8 plots for 1944. The 1943 values are averages for samples taken in 1939 and 1945.

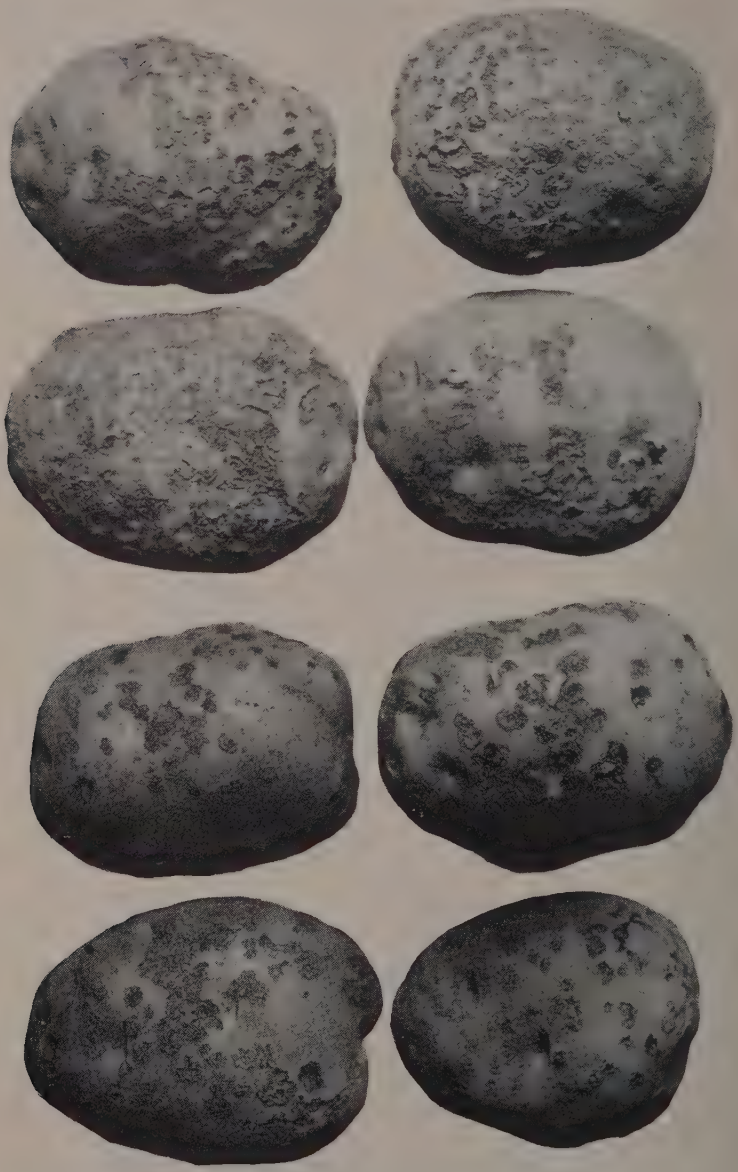

FIGURE 3. Representative tubers of the 1947 crop from plots receiving ground limestone in 1935 as follows:
Above—6000 pounds per acre.
Below—4000 pounds per acre.

plots became lower but had not returned to the original pH values by 1947 when the plots were last sampled. Plots receiving no broadcast application of lime or sulfur averaged 0.30 pH higher in 1937 than in 1935. There was considerable fluctuation in pH on these plots from sampling to sampling, but less than on limed plots or those receiving sulfur. Plots treated with one ton of sulfur per acre dropped in pH on the average by 1.10 from 1935 to 1937. In following years the pH of these plots tended to rise slightly but still averaged 0.60 pH lower in 1944 than before treatment.

Data in Table 5 show a very close relationship between the average soil pH and scab index values for each year. The data also show considerable variation in the amount of scab which had developed (as determined on the 1943, 1944, and 1945 crops) on strips of plots receiving the same treatment in 1935. As previously indicated, this appears to be due principally to the variation in the pH and other soil characteristics before the treatment. More scab developed on the less acid Washburn loam (North replicate) than on the more acid Caribou soil (South replicate). Liming markedly increased potato scab, as shown in Table 5 and Figure 3.

Untreated plots produced slightly scabby potatoes only on the Washburn soil, where the original pH was 5.40 or higher. No scab developed on unlimed plots of the well-drained Caribou series. A slight amount of scab also developed on a few plots of the Washburn soil where a ton of sulfur was applied. This indicates that on low, dark areas of Washburn soil where only scabby potatoes can now be produced, repeated treatments with sulfur or other acidifying materials may be necessary to eliminate scab. On badly infested areas such as this, it may not be practical to attempt to eliminate tuber scab.

Tables 5 to 7 indicate, on the average, some development of potato scab at average pH values of 5.00 or below. However, most scab developed on plots having a pH of 5.40 or higher. Values in the tables may be indicative of the pH that may be found for a soil sample taken from a field having an occasional scabby area. The average pH of the field, as shown by the composite sample, may be quite low, while further investigation may show that the scabby tubers are largely produced on small areas having a considerably higher soil pH.

*Relation of Scab Index to Calcium Content and pH of Soil in 1944 and 1945.* Data obtained on soil samples taken from the scab experiment in 1944 and 1945 and presented in Table 6 indicate that the amount of scab is closely related not only to pH but also to the amount of calcium in the soil. For a given soil which has been limed at different rates, the relationship between pH and calcium content is usually quite close. This relationship, however, varies considerably for different soils, depending upon the texture and the nature of the liming, fertilization, or other treatment of the soils. The relationship between potato scab and soil pH and calcium content has also been found by numerous other investigators to vary widely between different soils and climatic conditions.

TABLE 6

*Relation of Scab Index to Calcium Content and pH of Soil in 1944 and 1945*

| Amendments applied fall 1935 Acre rate | Scab index | Soil pH | Soluble[1] calcium— Lbs. Ca per acre | Exchangeable[2] calcium— Lbs. Ca per acre |
|---|---|---|---|---|
| 1944[3] (Section II): | | | | |
| 6000 lbs. ground limestone | 40.2 | 5.90 | 2850 | 3130 |
| 4000 lbs. ground limestone | 23.6 | 5.75 | 2960 | 2830 |
| 2000 lbs. ground limestone | 3.0 | 5.40 | 2390 | 2360 |
| Nothing | 0.4 | 4.95 | 1850 | 1800 |
| 2000 lbs. sulfur | 0.1 | 4.40 | 930 | 920 |
| 1945[3] (Section I): | | | | |
| 6000 lbs. ground limestone | 43.6 | 6.05 | 5860 | 4340 |
| 4000 lbs. ground limestone | 19.1 | 5.85 | 5500 | 4000 |
| 2000 lbs. ground limestone | 6.7 | 5.60 | 4760 | 3570 |
| Nothing | 1.3 | 5.25 | 3680 | 2810 |
| 2000 lbs. sulfur | 0.1 | 4.60 | 1450 | 1420 |

[1] Soluble in acetic acid-sodium acetate solution at pH 4.80.
[2] Removed from soil by leaching with neutral normal ammonium acetate.
[3] Average of 12 plots for 1944 and of 6 plots for 1945.

*Effect of Ammonium Sulfate and Sulfur Applied in 1946 and 1947 on Soil pH and Reduction in Scab.* Since the ammonium sulfate and sulfur acidifying treatments were superimposed in a random manner on the older treatments applied in 1935, the soil pH values given in Table 7 are not comparable with average pH values given for 1944 and previous years in other tables. The 1944 data given in the table indicate the pH and scab conditions on the particular plots which received the 1946 and 1947 treatments.

Chemically, the acidifying value of the materials applied in terms of pounds of calcium carbonate ($CaCO_3$) are approximately as follows:

| Material | Acre rate—pounds | Equivalent—pounds $CaCO_3$ |
|---|---|---|
| Ammonium sulfate | 400 | 300 |
| " " | 800 | 600 |
| " " | 1200 | 900 |
| Sulfur | 300 | 940 |
| " | 600 | 1880 |
| " | 900 | 2820 |

TABLE 7

*Effect*[1] *of Broadcast Applications of Sulfur in 1946 and of Ammonium Sulfate in 1946 and 1947 on Soil pH and Scab Index of Tubers*

| Broadcast treatment—Acre rates[2] | 1944—Before applications | | 1946 Sulfur or ammonium sulfate | | 1947—Ammonium sulfate only | |
|---|---|---|---|---|---|---|
| | Av. scab index | Av. soil pH | Av. scab index | Av. soil pH | Av. scab index | Av. soil pH |
| Plots receiving 6000 lbs. ground limestone in 1935: | | | | | | |
| Nothing | 46.9 | 5.85 | 58.8 | 5.85 | 58.1 | 6.10 |
| 300 lbs. S. | 36.4 | 5.95 | 40.7 | 5.70 | 45.1 | 5.95 |
| 600 lbs. S. | 40.5 | 6.05 | 46.8 | 5.75 | 45.2 | 6.05 |
| 900 lbs. S. | 28.2 | 5.65 | 16.9 | 5.25 | 12.7 | 5.30 |
| 400 lbs. A.S. | 44.6 | 6.00 | 53.1 | 5.85 | 46.4 | 5.80 |
| 800 lbs. A.S. | 39.4 | 6.15 | 25.4 | 5.90 | 9.5 | 5.50 |
| 1200 lbs. A.S. | 45.1 | 5.80 | 22.6 | 5.85 | 7.7 | 5.00 |
| Plots receiving 4000 lbs. ground limestone in 1935: | | | | | | |
| Nothing | 29.7 | 5.75 | 44.5 | 5.70 | 44.9 | 6.00 |
| 300 lbs. S. | 18.3 | 5.90 | 22.2 | 5.60 | 28.1 | 5.95 |
| 600 lbs. S. | 35.3 | 6.00 | 27.2 | 5.75 | 34.2 | 5.95 |
| 900 lbs. S. | 19.4 | 5.65 | 11.1 | 5.10 | 7.8 | 5.20 |
| 400 lbs. A.S. | 35.0 | 5.80 | 38.9 | 5.75 | 31.3 | 5.75 |
| 800 lbs. A.S. | 21.7 | 5.80 | 21.4 | 5.75 | 2.9 | 5.60 |
| 1200 lbs. A.S. | 21.2 | 5.70 | 13.9 | 5.30 | 2.4 | 4.90 |
| Plots receiving 2000 lbs. ground limestone in 1935: | | | | | | |
| Nothing | 4.2 | 5.45 | 14.4 | 5.35 | 7.6 | 5.70 |
| 300 lbs. S. | 5.1 | 5.55 | 6.1 | 5.40 | 2.6 | 5.65 |
| 600 lbs. S. | 6.4 | 5.65 | 5.3 | 5.25 | 3.8 | 5.50 |
| 900 lbs. S. | 0 | 5.25 | 0.1 | 4.75 | 0.1 | 4.85 |
| 400 lbs. A.S. | 7.6 | 5.55 | 5.7 | 5.50 | 2.5 | 5.55 |
| 800 lbs. A.S. | 2.7 | 5.40 | 1.6 | 5.20 | 0.2 | 5.15 |
| 1200 lbs. A.S. | 1.6 | 5.15 | 1.1 | 4.95 | 0 | 4.55 |
| Plots receiving no broadcast treatment in 1935: | | | | | | |
| Nothing | 0.9 | 5.05 | 0.4 | 5.05 | 0.9 | 5.40 |
| 300 lbs. S. | 0.6 | 5.10 | 0 | 5.10 | 0.5 | 5.30 |
| 600 lbs. S. | 0.6 | 5.05 | 0.7 | 4.90 | 0.7 | 5.10 |
| 900 lbs. S. | 0 | 4.80 | 0 | 4.45 | 0 | 4.75 |
| 400 lbs. A.S. | 1.0 | 5.10 | 0 | 5.10 | 0.4 | 5.05 |
| 800 lbs. A.S. | 0 | 4.85 | 0.3 | 4.75 | 0 | 4.65 |
| 1200 lbs. A.S. | 0 | 4.90 | 0 | 4.70 | 0 | 4.20 |
| Plots receiving 2000 lbs. sulfur in 1935: | | | | | | |
| Nothing | 0.3 | 4.45 | 0.6 | 4.50 | 0.1 | 4.75 |
| 300 lbs. S. | 0.2 | 4.55 | 0 | 4.50 | 0 | 4.60 |
| 600 lbs. S. | 0 | 4.40 | 0 | 4.30 | 0 | 4.50 |
| 900 lbs. S. | 0 | 4.25 | 0 | 4.10 | 0 | 4.20 |
| 400 lbs. A.S. | 0 | 4.30 | 0 | 4.40 | 0 | 4.50 |
| 800 lbs. A.S. | 0 | 4.25 | 0 | 4.25 | 0 | 4.15 |
| 1200 lbs. A.S. | 0 | 4.40 | 0 | 4.15 | 0 | 3.95 |

[1] Each value is the average of 4 plots for no treatment and of 2 plots for sulfur and ammonium sulfate.
[2] S.—Sulfur; A.S.—Ammonium sulfate.

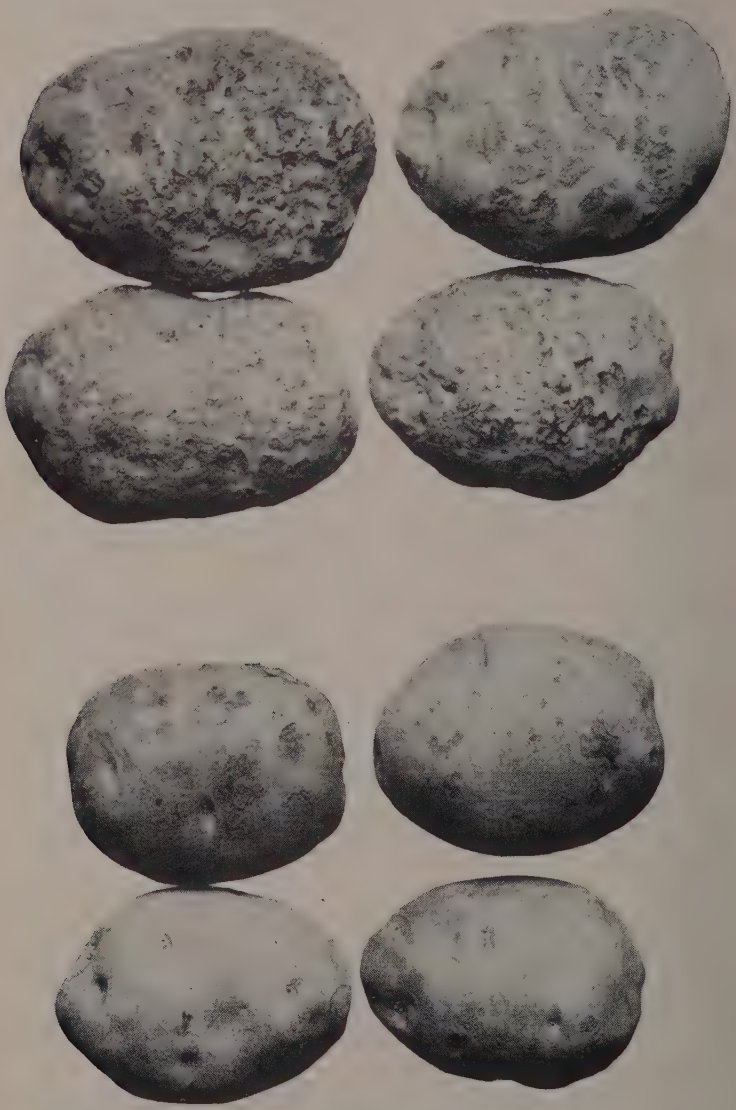

FIGURE 4. Representative tubers of the 1947 crop from plots receiving 6000 pounds of ground limestone per acre in 1935 and treated with ammonium sulfate in 1946 and 1947 as follows:
Above—400 pounds ammonium sulfate per acre.
Below—1200 pounds ammonium sulfate per acre.

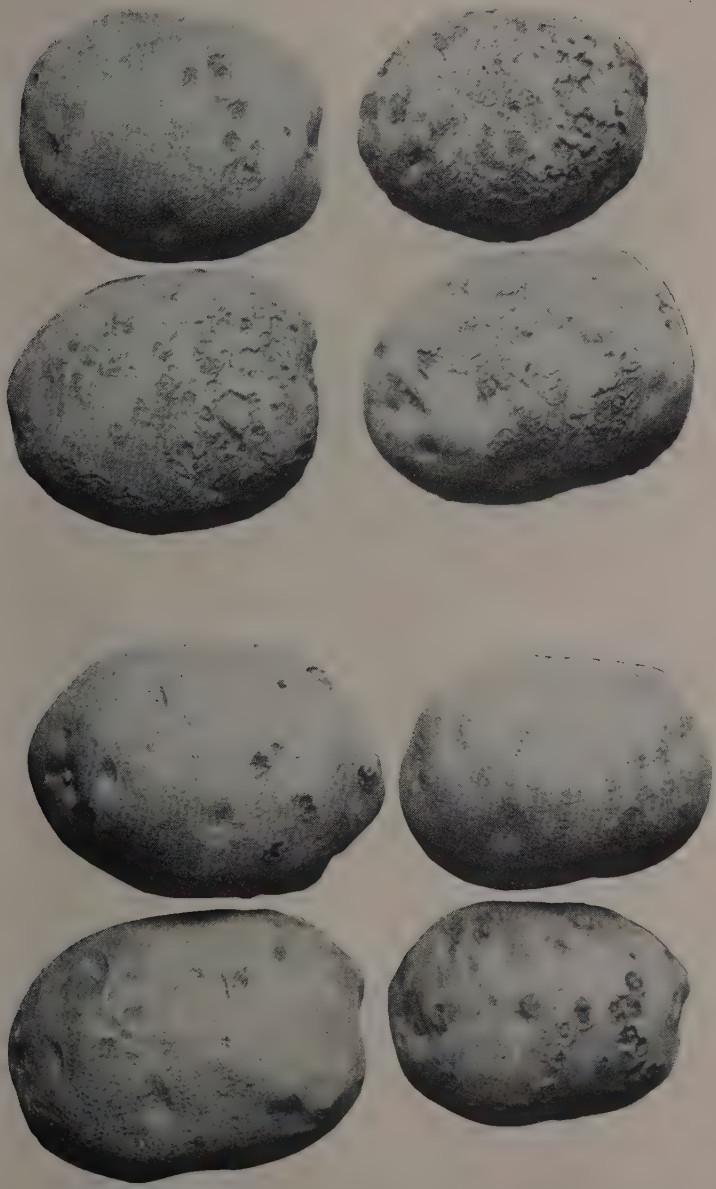

FIGURE 5. Representative tubers of the 1947 crop from plots receiving 6000 pounds ground limestone per acre in 1935 and treated with sulfur in 1946 as follows:
Above—300 pounds sulfur per acre.
Below—900 pounds sulfur per acre.

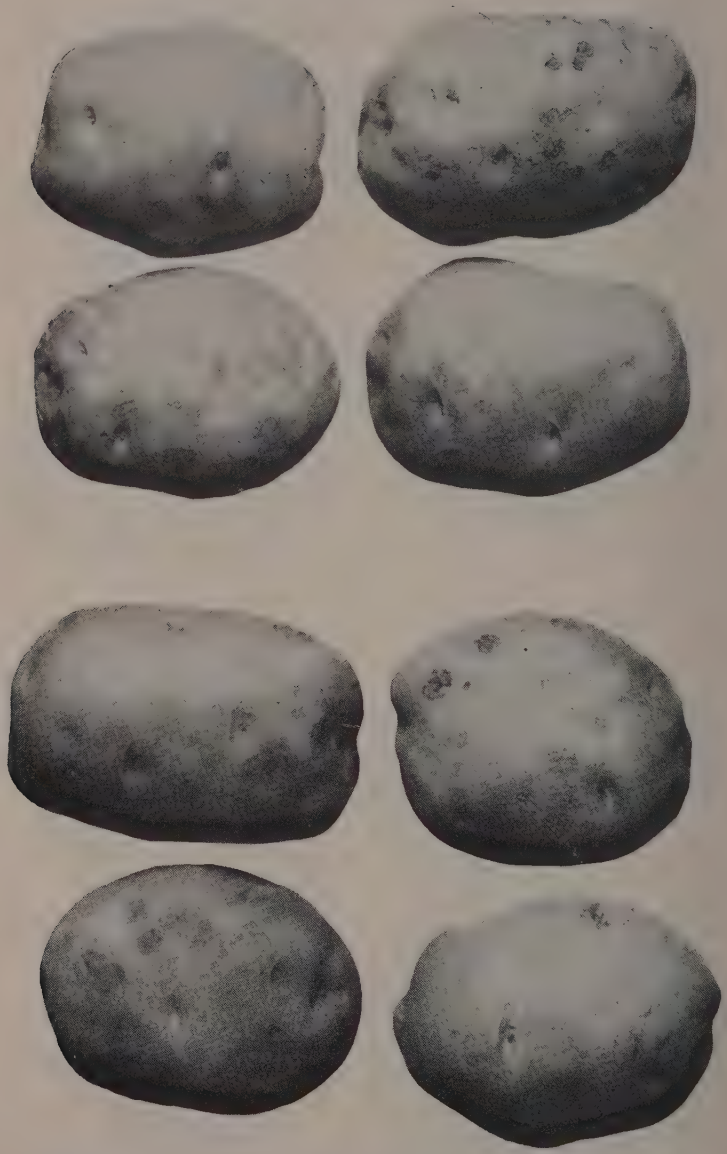

FIGURE 6. Representative tubers of the 1947 crop from plots receiving two rates of ground limestone in 1935 and 800 pounds ammonium sulfate per acre in 1946 and 1947:
Above—2000 pounds ground limestone applied in 1935.
Below—4000 pounds ground limestone applied in 1935.

Ammonium sulfate, although much lower in potential acidifying capacity, is quite soluble and its acidifying effect is made apparent sooner than is that of sulfur. Sulfur, while having a high potential acidifying capacity, is largely insoluble at first and must be oxidized, or acted upon by sulfur-oxidizing organisms in the soil before it becomes effective.

Results given in Table 7 indicate that the effect of the two materials on scab in 1946 is more nearly the same pound for pound than in proportion to their potential acidifying capacity. The ammonium sulfate applications made in 1946 and repeated in 1947 were considerably more effective in reducing scab over the two-year period than the sulfur applications made only in 1946. The sulfur was not applied again in 1947 because of the possible toxic effect on the potatoes, as resulted from the 2000 pound application in 1935. Plowing in the fall of 1946 may have placed some of the sulfur applied in 1946 where it was less effective in reducing scab in the 1947 crop. Effectiveness of sulfur might have been increased by inoculation with sulfur-oxidizing organisms, as recommended by Martin (3) and others. The 300 and 600-pound rates of sulfur and the 400-pound rate of ammonium sulfate were relatively ineffective in reducing scab. Over the two-year period the 800-pound rate of ammonium sulfate was slightly more effective in reducing scab than the 900-pound rate of sulfur. The treatment with 1200 pounds of ammonium sulfate was most effective in eliminating scab (Figures 4 and 5). On some plots producing badly infected tubers in 1944, this treatment resulted in clean or nearly clean tubers in 1947, even on the high-lime plots. At the lower liming rates, 800 pounds of ammonium sulfate resulted in nearly clean tubers in 1947, as shown in Figure 6.

## EFFECT OF GREEN MANURE CROPS AND OTHER ORGANIC TREATMENTS

*Effect on Yield of Potatoes.* In Table 8 are listed the various organic treatments which were compared from 1936 through 1945. On Section II significant increases were found between average yields for the various treatments for every year this section was cropped to potatoes. These differences, however, are not very consistent for the different years. Data in Table 8 indicate that as an

TABLE 8

*Effect of Green Manure Crops and Other Organic Treatments on Yield of Potatoes*[1]

| Green manure crop or other treatment for each potato crop | Yield—Bushels per acre | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1936[2] | 1937 | 1938 | 1939 | 1940 | 1941 | 1942 | 1943 | 1944 | 1945 | Av. for Sec. I (odd years) | Av. for Sec. II (even years) |
| Oats, crop removed (Check) | 492 | 322 | 358 | 354 | 371 | 468 | 414 | 508 | 411 | 377 | 406 | 409 |
| Buckwheat | 555 | 330 | 335 | 334 | 378 | 453 | 355 | 558 | 400 | 377 | 410 | 405 |
| Crimson clover | 543 | 324 | 304 | 343 | 330 | 514 | 413 | 480 | 410 | 385 | 409 | 407 |
| Oats, crop removed, plus 20 tons manure | 541 | 338 | 339 | 386 | 372 | 457 | 455 | 441 | 412 | 342 | 393 | 424 |
| Oats, crop removed, plus 6 tons straw | 511 | 385 | 364 | 387 | 404 | 491 | 445 | 472 | 442 | 389 | 425 | 433 |
| Oats, crop removed, plus 2 tons peat | 551 | 343 | 369 | 380 | 392 | 428 | 439 | 515 | 424 | 382 | 410 | 435 |
| Significant difference:[3] | | | | | | | | | | | | |
| 5% level— | 35 | — | 24 | — | 34 | — | 35 | — | 24 | — | N.S. | 14 |
| 1% level— | 48 | — | 32 | — | N.S. | — | 47 | — | N.S. | — | N.S. | 18 |

[1], [2], [3] See Table 1, footnotes 2, 3, and 4, respectively.

average of five potato crops, the plots planted to buckwheat or crimson clover green manure crops yielded essentially the same as the check plots, which were planted to oats and the crop removed. On Section I the average yields for the five potato crops show no significant difference between the various organic soil treatments. Without replication, possible significant differences for each year could not be estimated. The rather high content of organic matter in the soil on the experimental area no doubt influenced the results obtained. The results obtained in this experiment are in general agreement with the results of other experiments at Aroostook Farm, in which only slight differences have resulted in the yields of potatoes following various green manure crops.

*Effect on Potato Scab and Potassium Content of the Soil.* Results of some experiments with potato scab at other places have shown an effect of certain cropping practices and organic treatments on potato scab. Data in Table 9, however, indicate little relationship between potato scab and the green manure crops or the manure, straw, or peat plowed under for potatoes. The average differences in scab index values are not consistent with treatment for 1944 as compared to 1945. The differences in scab development appear to be more closely related to the differences in the soil on

TABLE 9

*Effect of Organic Treatments in a 2-year Rotation on Scab Index of Tubers and pH and Potassium Content of Soil in 1944 and 1945*

| Organic amendment | Scab index | Soil pH | Soluble[1] potassium Lbs. K per acre | Exchangeable[2] potassium Lbs. K per acre |
|---|---|---|---|---|
| 1944[3] (Section II): | | | | |
| Oats, straw removed (check) | 18.2 | 5.40 | 360 | 330 |
| Buckwheat | 13.5 | 5.40 | 560 | 560 |
| Crimson clover | 11.5 | 5.20 | 470 | 515 |
| Oats, straw removed, plus 20 tons manure | 16.1 | 5.25 | 740 | 785 |
| Oats, straw removed, plus 6 tons straw | 11.3 | 5.20 | 465 | 490 |
| Oats, straw removed, plus 2 tons peat | 10.0 | 5.15 | 330 | 375 |
| 1945[3] (Section I): | | | | |
| Oats, straw removed (check) | 7.6 | 5.35 | 215 | 265 |
| Buckwheat | 10.6 | 5.30 | 180 | 175 |
| Crimson clover | 14.4 | 5.40 | 210 | 210 |
| Oats, straw removed, plus 20 tons manure | 14.7 | 5.55 | 510 | 585 |
| Oats, straw removed, plus 6 tons straw | 17.8 | 5.65 | 460 | 430 |
| Oats, straw removed, plus 2 tons peat | 19.8 | 5.60 | 270 | 195 |

[1] Soluble in pH 4.80 acetic acid-sodium acetate solution.
[2] Removed from soil by leaching with neutral normal ammonium acetate.
[3] Average of 10 plots for 1944 and of 5 plots for 1945.

which the treatments were located than to the treatments themselves.

The chief effect of certain organic soil amendments was on the potassium content of the soil. Application of 20 tons of manure for each potato crop on Section I increased the exchangeable soil potassium more than two times over the average of plots where oat stubble, buckwheat or crimson clover crops were plowed under. Application of 6 tons of straw also increased the exchangeable potassium. Application of peat, which is very low in potassium, had no effect.

## COOK FARM EXPERIMENT

In the spring of 1942 a liming experiment was begun on the Cook Farm, about one mile south of Aroostook Farm in the town of Presque Isle. The soil was an acid Caribou loam having a pH of 4.4 to 4.7. Three finely ground materials were applied, namely: calcium limestone (52 per cent CaO and less than 3 per cent MgO),

TABLE 10

*Effect of Limestone and Gypsum on Clover Yields, pH and Calcium Content of Soil and Scab Index of Katahdin Tubers*

| Treatments applied in 1942— Acre rates | 1944 results | | | Scab index of potato tubers | |
|---|---|---|---|---|---|
| | Clover yield— Lbs. dry matter per acre | pH of soil | Soluble calcium[1] Lbs. Ca per acre | 1945 crop | 1946 crop |
| No lime | 940 | 4.75 | 780 | 0 | **0** |
| Calcium limestone: | | | | | |
| 500 lbs. | 870 | 4.85 | 780 | 0 | **0** |
| 1000 lbs. | 950 | 4.90 | 960 | 0 | **0** |
| 2000 lbs. | 4430 | 5.05 | 1110 | Trace | **0** |
| 4000 lbs. | 5290 | 5.35 | 1990 | 1.9 | **2.7** |
| Magnesium limestone: | | | | | |
| 500 lbs. | 1210 | 4.95 | 940 | 0 | **0** |
| 1000 lbs. | 2520 | 5.05 | 1020 | 0 | **0** |
| 2000 lbs. | 5020 | 5.25 | 1300 | Trace | **0** |
| 4000 lbs. | 4300 | 5.20 | 1140 | 0.3 | **0.6** |
| Gypsum: | | | | | |
| 1000 lbs. | 610 | 4.85 | 900 | 0 | **0** |
| 2000 lbs. | 770 | 4.75 | 990 | 0 | **0** |
| 3000 lbs. | 660 | 4.80 | 980 | 0 | **0** |
| 4000 lbs. | 720 | 4.75 | 1020 | 0 | **0** |

[1] Soluble in acetic acid-sodium acetate solution adjusted to pH 3.0 with hydrochloric acid.

FIGURE 7. Small amounts of lime on very acid potato soils may be insufficient to obtain good clover stands. Left—Poor stand of clover with 1000 pounds magnesium limestone per acre. Right—No stand of clover with 500 pounds per acre.

magnesium limestone (33 per cent CaO and 18 per cent MgO), and gypsum (calcium sulfate). All materials were applied broadcast to the soil and harrowed in prior to planting potatoes. Rates of application are given in Table 10.

A few tubers of the 1942 potato crop from the plot receiving 4000 pounds of calcium limestone showed a trace of scab. Scab-free tubers were produced on all other plots of the experiment.

The plots were seeded to oats and mammoth clover in 1943. The resulting stands of clover in 1944 are shown on the cover page and in Figures 7 and 8. Yields of clover for the various treatments are given in Table 10. No clover survived where lime was not applied. An occasional clover plant remained on plots receiving 500 pounds of calcium or magnesium limestone per acre and plots limed at the 1000 pound rate had but a poor stand of clover (Figure 7). Where 2000 pounds was applied (Figure 8 and cover page), a good stand of clover resulted, and where 4000 pounds was applied, both stand and growth were excellent. As shown in Table 10, the yield of clover was somewhat better where the magnesium lime-

Figure 8. Gypsum has no effect on clover stands. Left—Good stand of clover with 2000 pounds ground limestone per acre. Right—No stand of clover with 4000 pounds of gypsum per acre.

stone was used. Gypsum failed to benefit the stand of clover (Figure 8) even at the 4000 pound rate of application.

In 1945 the experimental area was again planted to potatoes. A trace of scab was found on a few tubers from plots receiving 2000 pounds of limestone in 1942 and somewhat more scab on plots receiving 4000 pounds. By weight, 60 per cent of the tubers from the plots limed with 4000 pounds of calcium limestone were scab-free, 23 per cent had a trace of scab and 17 per cent had more than a trace, resulting in an approximate scab index of 1.9. On the plots limed with 4000 pounds of magnesium limestone, 93 per cent of the tubers by weight were scab-free, 5 per cent had a trace of scab, and 2 per cent had more than a trace. Gypsum had no effect on scab. In 1946 the plots were again planted to potatoes. No scab was found on any plots except those limed at the 4000 pound rate in 1942. On these plots there was slightly more scab than the previous year.

Yields of potatoes on the plots were not determined. The Katahdin variety, one which is more resistant to scab than Green Mountains, was grown on these plots. More scab might have developed had the Green Mountain variety been grown.

## RECOMMENDATIONS

*Liming Recommendations.* In respect to the potato scab problem, liming materials should not be applied to the finer-textured potato soils in amount to exceed 2000 pounds of ground limestone (100 per cent $CaCO_3$ or 56 per cent CaO equivalent) per acre per application. On sandy soils the maximum amount per application should not exceed 1000 pounds.

The following points are important in liming potato soils so as to reduce the danger of potato scab.

1. Use finely ground materials. Either ground limestone, $CaCO_3$ or $MgCO_3$, or hydrated lime, $Ca(OH)_2$ or $Mg(OH)_2$, is satisfactory. Ground limestone containing not less than 10 per cent MgO is recommended for potato soils in Maine. Fine material dissolves more readily and is less likely than coarse to develop a local high pH around the lime particles, which favors development of the scab organisms.

2. Spread liming materials evenly. A good lime spreader in proper mechanical condition is the best tool to use. Uneven spreading may result in spots or streaks in the field having a local high pH, which favors scab development.

3. Have soil tests made on your fields. Intelligent liming recommendations can be made only if the acidity, or soil reaction (pH), and calcium and magnesium contents of the soil are known.

4. The following schedule of liming rates may serve as a guide for applying lime, if the pH of the soil is known.

| | Pounds of ground limestone recommended per acre for loam or silt loam soils |
|---|---|
| pH 5.4 and above | None |
| pH 5.2-5.3 | 500 |
| pH 5.0-5.1 | 1000 |
| pH 4.6-4.9 | 1500 |
| Below pH 4.6 | 2000 |

If the available calcium content of the soil is high, no lime is recommended above pH 4.8. If the calcium content is medium, none is recommended above pH 5.2. If the calcium content is low, the recommendation is based entirely on the pH value, as indicated above.

On sandy soils no lime is recommended above pH 5.2. At lower pH values the recommendations for loam or silt loam soils should be cut in half.

5. The time lime is applied is not too important, as far as the effect on potato scab is concerned. However, if clover or other legumes are grown in the potato rotation, lime should be applied at the time of seeding.

*Treatment of Areas Producing Scabby Potatoes.* Results of experiments indicate that some scabby areas can be eliminated rather easily by application of soil-acidifying materials, such as sulfur and ammonium sulfate. Amounts of sulfur or ammonium sulfate recommended to be broadcast before planting potatoes are as follows:

1. Mildly scabby areas—400 to 500 pounds per acre.
2. Moderately scabby areas—600 to 700 pounds per acre.
3. Very scabby areas—800 to 900 pounds per acre.

Choice between the two materials should be made largely on the basis of their cost and availability. Despite the higher potential acidifying capacity of sulfur, the two materials appear to have a similar effect in reducing potato scab when applied at the same rate.

Conditions where it is probably not practical to attempt to eliminate scab by soil-acidifying treatments include:

1. Severely scabby areas of dark, poorly drained soils rather high in pH.
2. Scabby areas on very shallow soils where calcareous, or limy ledge outcrops, or where calcareous gravel occurs at or near the surface of the soil.

   On such areas probably the best solution is to change to crops other than potatoes or to a more scab-resistant potato variety.
3. Where scab occurs on soils having a pH of 5.0 or below. Making such soil more acid is likely to result in lower potato yields. More research is necessary before recommendations can be made on these soils. At present the use of scab-resistant varieties is the best solution known.

*Cropping Recommendations.* Many farmers and investigators have found that crop rotation is at least a partial answer to the potato scab problem. As is the case with many soil-borne plant diseases, including potato scab, the more frequently potatoes are grown, the greater is the rate of increase of potato tuber scab organisms.

In many cases where potato scab occurs at a soil pH of about 5.4 or below following an application of lime, the appearance of scab may be due more to continuous cropping of the soil to potatoes than to the lime application. Under these conditions, rotation of potatoes with green manure crops might result in cleaner potatoes.

*Potato Varieties Resistant to Potato Scab.* Varieties very susceptible to scab, such as Green Mountain, Irish Cobbler and Chippewa, should be replaced by more scab-resistant varieties on soils which tend to produce scabby potatoes. Katahdin is somewhat scab-resistant, and Sebago is still more scab-resistant. Seneca, Menominee, Cayuga, and other scab-resistant varieties have been developed, but these varieties are not recommended in Maine. Ontario, which compares favorably in yield with leading varieties,

is highly resistant to scab and is recommended in Maine where scab is a serious problem.

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